

4.3 NEEDS FOR REGISTRATION AND RECTIFICATION OF SATELLITE IMAGERY FOR LAND USE AND LAND COVER AND HYDROLOGIC APPLICATIONS

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ABSTRACT

Many land use and land cover and hydrologic applications require the use of satellite imagery and data. Maps and aggregations are made from the data which might exist in concert with other data in a geographic information system. Users have basic needs for registration and rectification of satellite imagery related to specifying, reformatting, and overlaying the data. Presently, each user must accomplish these tasks independently because the present data pre-processing system is unreliable. These data are sufficient for users who must expend much effort in registering data. These users have requirements concerning projection, pixel size, resampling, and accuracy, and most would be satisfied with data that met the standards proposed, but not consistently achieved, for the present system.

APPLICATIONS

Users of satellite imagery for land use and land cover or hydrologic applications generally are interested in interpreting land use and land cover from the data to produce maps and aggregations, inputting the data into geographic information systems, detecting changes over time, and using derived data in a predictive fashion (ORI, 1979). Ancillary data is important in every step, and the ability to incorporate such data into the analysis process directly increases utility for such applications as inventorying, managing, and planning. The hydrologic application is really a subset of the more general land use and land cover applications. Frequently, particular categories of land use and land cover affecting the hydrologic budget (such as irrigated agricultural land) are mapped and utilized in hydrologic models (much like geographic information systems) with other data sets.

Those users interested in areas at least as large as multiple counties make most use of the present generation of satellite imagery. We'll focus on one prospective user, the U.S. Geological Survey (USGS) to illustrate needs most other users can be expected to have.

USGS began a program in 1974 to map land use and land cover for the entire Nation, to digitize the resulting polygons, and to make the data available for use in geographic information systems. Although present satellite data have not been used as primary source material, data from improved sensor packages may prove more useful. In any case, satellite data can be expected to play a role in identifying areas in need of updating (Milazzo, 1980), and Landsat digital data have proved valuable in regions where other source material is lacking (Morrissey and Ennis, 1981).

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The Water Resources Division of USGS has a need to map specific categories of land use and land cover as an indirect estimator of water use. Field measurements and ancillary data are used to determine the average amount of water used for each hectare of a given land use and land cover. The resulting data are used in combination with other layers of data such as recharge and discharge rates and present saturated thickness of an aquifer to predict future saturated thickness given alternative water use plans. A hydrologic model is used for this application in much the same way that a geographic information system might be used to relate multiple layers of data.

BASIC NEEDS

Land use and land cover and hydrologic applications users have basic needs for registration and rectification of satellite imagery: (1) the users must be able to locate data when given geographic coordinates or to find geographic coordinates given data coordinates; (2) it must be possible to reformat the data to fit given map projections; and (3) scenes of the same area from different times must overlay each other.

Presently, each user solves these problems independently with different degrees of success and at varying costs. Typically the user first finds a set of 30 or more control points for a Landsat scene that can be identified on the imagery and on the largest scale maps available. Methods differ somewhat. Some users identify control points from a digital display. Others print grayscales for areas surrounding likely control points on a lineprinter and correlated them with topographic maps. Map coordinates are determined either through measurement with a latitude/longitude or Universal Transverse Mercator (UTM) coordinates. Second- or third-degree polynomials are computed by analyzing the control points and discarding those inaccurately determined. These polynomials are used as a calibration file to reference the data. Other data can then be registered to the Landsat base through the calibration file even though that base might not actually be itself registered to a map.

For display of Landsat data as a map, though, additional processing is required. Typically the Landsat data will be registered to a map base by specifying a calibration, desired projection, size of final pixel, and resampling scheme. This precision reformatting is a computation-intensive procedure, and not every user is able to accomplish it.

Utilizing more than one Landsat scene, either to make use of temporal data in an analysis or to detect change with time, requires registration of one scene to another. Again there are many ways to accomplish this task. Some users use a modified version of the control point procedure used to register a scene with a map. A digital display or grayscales are used to find control points on each scene, and calibration is established based on a polynomial. A less labor-intensive method is to use autocorrelation techniques, sometimes combined with gradient identification techniques, on a computer. This automatically finds control points that

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can then be edited. In addition to the labor-saving advantages, such systems frequently are able to find many more control points than the analyst is willing to find, say 200 rather than 50. Errors are usually less with more control. After the equations are established, one scene is considered the primary scene, and the other is "rubber-sheeted" to fit it, another intensive computation job. Though many users are interested in using multitemporal data for analysis, not everyone can carry it out, given the procedures required today.

PRESENT LIMITATION

The techniques outlined to solve present registration problems have been around for at least 5 years. EDIPS data have been around for 2 1/2 years. The same procedures used before EDIPS to solve registration problems are as necessary today as they were before EDIPS became available. There was great hope that the Master Data Processor (MDP) at Goddard would alleviate many of the problems and provide reliably corrected data. The Landsat data corrected with ground control points (GCP) chosen from 1:24,000-scale maps would be less than one pixel for 90 percent of the pixels in a scene. The Landsat Data-Users' Handbook also specified that the temporal registration offsets between two Landsat scenes having the same path-row location would be less than 0.5 pixel for 90 percent of the pixels in a scene (U.S. Geological Survey, 1979).

Those expectations are not being met. The U.S. Department of Agriculture (USDA) compared registration quality of data from the MDP with their existing techniques and found that though they could not rely on it presently, they could use data from the MDP as a starting point for an algorithm that will automatically register their segment data to the Landsat data (Graham and Luebke, 1981). The Digital Mapping of Irrigated Cropland Technique Testing project found it necessary to manually find control points for 36 scenes in 1981 because results of testing those Landsat scenes from the High Plains with assessment ratings of three or more where an average of no closer than ten pixels from their expected locations (Koch, 1981).

The same Technique Testing project found that not only was it necessary to find control points for scene to scene registration (multitemporal), but there was more rotation of one scene with respect to another with data from the MDP than there had ever been before. The increase in rotation requires much more computer memory for the "rubber sheeting" algorithm. On the positive side, EDIPS data seemed to correlate better than the old x-format, presumably because of the cubic convolution resampling. This improvement was also noted by the California Irrigated Lands Technique Testing project (E. Bauer, oral commun., 1981).

REQUIREMENTS

The present registration of Landsat data products is insufficient for the needs of land use and land cover and hydrologic applications users. Much time and effort is expended in referencing the data by map coordinates,

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precision correcting it to fit maps, and overlaying multitemporal scenes. These steps could be simplified considerably and even eliminated for some applications if data was really available in registered form. User demands in this area are not extreme. It is fair to presume that those users presently dissatisfied with data registered by the MDP would be quite happy with data that was registered as well as they are able to obtain themselves.

Users with the ability to perform their own geometric corrections would like Landsat data to come with information on image geometry (like listings of ground control points) sufficient for facilitating geometric corrections (ORI, 1979). This is probably the most common demand heard. Users would like listings of control points. With them they could perform their own corrections, check out the accuracies of their system-corrected data, or use them as a base for adding additional points when warranted.

Those users who would like system-corrected data are divided on questions of projection, rotation, pixel size, resampling, and accuracy. Let's look at each question, one at a time.

All users will not be satisfied with data in just one standard projection, such as the Space Oblique Mercator (SOM) or Hotine Oblique Mercator (HOM). Users of satellite imagery for land use and land cover applications commonly use the data in combination with maps and other data layers. These maps can be cast on a variety of projections, such as the UTM, Albers Conical Equal Area, or polar Stereographic. What is needed is the ability to convert data from one projection to another. USGS does have a package of computer routines, in Fortran, designed to permit the transformation of coordinate pairs from one map projection to another (U.S. Geological Survey, 1981). Data could be made available in one or two standard projections with software available to the users to convert to other projections, or the list of available projections could be expanded for the standard product with the user specifying his choice.

Most users would prefer land use and land cover data that are geometrically corrected before delivery to them to be rotated to North. Though arguments can be made that rotation is not really necessary, the fact remains that when working with maps, and other data levels derived from maps, rotated data is a pleasure and unrotated data is a pain. There is a dilemma with respect to this question. When working with an entire Landsat scene or multiple scenes, a rotated data set is substantially larger than its unrotated counterpart. When working with a map quadrangle, though, rotated data fit just right, and substantially more data are needed to get the quadrangle coverage from the unrotated set. So it really depends on the application and the size of the area of concern. The question of rotation should really be an option for the user. This would satisfy all.

Three pixel sizes seem to vie for attention. The 57-meter square delivered with EDIPS seems to garner no real harsh feelings. Users understand that 57 meters is the resampling interval along a scan line

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and they understand the logic of choosing that for the resampled pixel. There are perhaps stronger arguments to be made for going to a 50-meter square pixel since it would correspond quite nicely to UTM coordinates and be compatible with the cell size of the USGS land use and land cover data in the grid cell form. There are also those who would like to see 60-meter pixels which would be easier to compare with 30-meter thematic-mapper data.

There has also been much disagreement over resampling. Most users who do their own geometric corrections tend to use simple nearest neighbor, mostly because of cost considerations. Cubic convolution does appear to provide smoother looking data. It does so by increasing the variability of the pixel values making the data harder to compress and perhaps adversely affecting the accuracy of classification algorithms that utilize variance. Much of what resistance there is to convoluted data is probably due more to unfamiliarity with it than to other factors.

The question of accuracy is probably the single most important issue. At a minimum, users would like to know what the average accuracy of a particular product is. This is important above all else. If it is reasonable to achieve only 10-pixel accuracy for a given scene, because many 15-minute maps had to be used, the user needs to know. He can then determine whether that accuracy is sufficient for his application and improve upon it if necessary or possible. Perhaps the greatest disappointment from the AgRISTARS evaluation of data registration was the poor correlation that was found between accuracy and assessment ratings (Graham and Luebbe, 1981).

There are three distinct accuracies the user must worry about. The first involves the referencing problem. It may be necessary to extract pixels that lie within polygons digitized from a map. Most users would tell you that for this they require root-mean-square (RMS) accuracies at least as good as 1 pixel. This can be achieved, however, in two stages. The first might reference the data to within several pixels, while the second must use local fit to achieve the sub-pixel accuracy desired.

For fitting the data to a map, the real consideration is scale. The National Map Accuracy standard for horizontal accuracy is 0.02 inches at scales smaller than 1:20,000 (Thompson, 1979). This translates to 254 meters at 1:500,000, 127 meters at 1:250,000, and 51 meters at 1:100,000. Judging from past performance it seems reasonable to expect precision-corrected Landsat data to fall somewhere between the standards for 1:500,000- and 1:250,000-scale maps. This should be quite acceptable for most users.

In a geographic information system environment, the resolution of the coarsest unit determines the effective resolution of the entire system. Since land use and land cover data are usually at a finer resolution than other data layers, such as soils, problems with inaccurate registration of a few pixels are not especially critical on the whole. In hydrologic

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applications over multi-State regions, land cover data from Landsat may be at the finest resolution of the system even though it is reported for areas as large as 1 square mile. Misregistration could be critical in particular cases, though. Identifying residential land use within a specified slope interval computed from digital elevation models of 15-meter resolution would require very good, sub-pixel registration. Registration becomes most critical when it comes to overlaying data collected from the same point at different times. The California Irrigated Lands Technology Transfer project attains a 0.2 pixel RMS error for multitemporal registration (Wall and others, 1981). Error tolerance depends mostly on environment and repetition. Larger errors can be tolerated if land use and land cover features are large and if only two dates are being overlaid. Those same errors become intolerable when the features are smaller (more boundary pixels) and when more scenes are being overlaid. In general, most users would be quite pleased with the error limits proposed for EDIPS, that is, 0.5 pixel temporal registration offset.

SUGGESTIONS

Most users are puzzled by the lack of quality registration coming out of the MDP. This has limited some users without access to their own geometric correction and overlaying algorithms and has increased costs substantially for the others. It is hoped that a result of the Registration and Rectification Workshop will be an improvement in the accuracy of MDP products. One critical element in any procedure to accurately register satellite imagery to maps is selection of ground control points. Thousands of control points have been picked by Landsat analysts in the past. Perhaps a way can be found to accept contributions of GCP's from the users into the MDP library. There they would augment those already in the library, increasing the number of points available for each scene and the reliability of registration.

SUMMARY

Reliable registration of satellite imagery would greatly increase the use of such data for land use and land cover and hydrologic applications. While some users can and do accomplish their own registration, most cannot. The inability to work with registered data results in the loss of the temporal dimension, production of inferior map products, and difficulty in using ancillary data that is registered. While sampling strategies satisfy users from some disciplines, land use and land cover are commonly interested in completing "wall to wall" surveys and producing map products.

Land use and land cover and hydrologic applications users have definite demands for registered satellite imagery. While more variety with respect to options is desirable, products which meet the standards proposed for EDIPS would be welcomed. One addition that most users mention is a listing of control points that can be used to check accuracy of a particular product or as a starting point for refinement. Satisfaction of those requirements would greatly improve the utility of satellite imagery for land use and land cover and hydrologic applications.

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